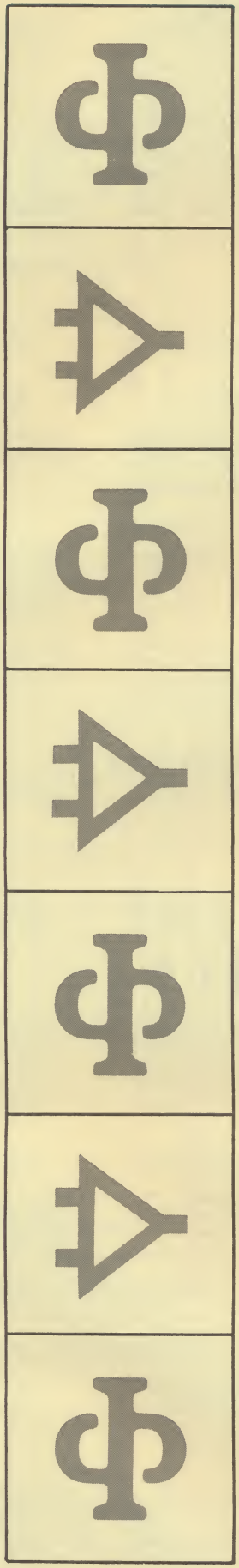
PHILBRICK RESEARCHES, INC.
ALLIED DRIVE at ROUTE 128, DEDHAM, MASSACHUSETTS 02026



PRICE LIST
1 DECEMBER 1966

PHILBRICK ELECTRONIC ANALOG COMPUTING EQUIPMENT

for

MODELLING MEASURING MANIPULATING & MUCH ELSE

Prices subject to change without notice
Minimum order $15.00

Terms: Net 30 Days
FOB: Dedham, Mass.

REPRESENTATIVES IN PRINCIPAL CITIES THROUGHOUT THE FREE WORLD

OPERATIONAL AMPLIFIERS

PREMIUM GRADE			
MODELS	1-4	5-14	15-24
P2A	$227	$218	$218
SP2A	180	178	175
SP2B	195	193	189
SP102	295	284	270
P12Q	145	138	130
PP12Q	145	138	130
P18Q	85	80	75
PP18Q	85	80	75
P25A	135	129	122
PP25A	135	129	122
P25AH	154	148	139
Q25AH	180	180	180
P35A	98	94	87
PP35A	98	94	87
P45A	118	110	98
P45AL	95	89	79
PP45	118	110	98
PP45L	95	89	79
P55A	49	48	46
P55AH	53	51	48
PP55A	49	48	46
PP55AH	53	51	48
P65A	65	63	61
P65AH	69	66	63
P65Q	69	66	63
PP65A	60	58	56
PP65AH	64	61	58
PP65Q	64	61	58
P75A	98	94	87
PP75A	98	94	87
P85A	65	63	61
P85AH	98	93	89
PP85A	60	58	56
Q85AH	161	161	161
SP456 *	227	217	204
SP65A *	180	171	161
SP65AH *	189	177	165
SP656 *	195	185	172

* SPECIFY "MECHANICAL" or "PHOTOCHOPPER"

UTILITY GRADE			
MODELS	1-4	5-14	15-24
P2AU	$130	$130	$130
SP2AU	138	138	138
SP2BU	145	145	145
P12QU	111	110	105
PP12QU	108	107	102
EP12QU	108	107	102
P18QU	62	60	57
PP18QU	59	57	54
EP18QU	59	57	54
P25AU	89	89	89
PP25AU	79	79	79
EP25AU	85	85	85
P35AU	62	62	62
PP35AU	54	54	54
EP35AU	60	60	60
P45AU	89	87	83
P45ALU	65	64	61
PP45U	89	87	83
PP45LU	65	64	61
EP45AU	87	85	81
P55AU	20	20	20
EP55AU	19	19	19
PP55AU	15	15	15
P55AHU	24	24	24
EP55AHU	24	24	24
PP55AHU	19	19	19
P65AU	33	33	33
P65AHU	37	37	37
P65QU	37	37	37
PP65AU	30	30	29
PP65AHU	34	34	32
PP65QU	37	37	37
EP65AHU	35	35	35
EP65QU	35	35	35
EP65AU	31	31	31
P75AU	68	66	63
PP75AU	68	66	63
P85AU	33	33	33
PP85AU	25	25	25
EP85AU	31	31	31

MODELS	1-4	5-14	15-24
P25C	$145	$139	$131
PP25C	145	139	131
P35C	118	113	107
PP35C	118	113	107
P45C	133	123	110
PP45C	135	125	112
P45CL	110	103	91
PP45CL	110	103	91
P65C	80	77	75
P65CH	84	80	77
PP65C	75	72	70
PP65CH	79	75	72
P85C	85	83	81
PP85C	80	78	76

Boosters

P5	$48	48	48
P66A	39	38	36
PP66A	40	39	37
OSPB-50/50	85	82	76
OSPB-100/10	85	82	76

PHILBRICK SOLID STATE EQUIPMENT

REGULATED POWER SUPPLIES

		1-4	5-14	15-24
OSPR30A	Chassis Plug-in	$ 93	$ 92	$ 91
OSPR30	Chassis Plug-in ±15V at ±30mA	93	92	91
SPR30A	Chassis Plug-in	98	97	96
SPR-30	Chassis Plug-in			
PR-30	Bench Unit ±15V at ±30mA	98	97	96
PR-30C	Chassis Unit			
PRH-60	Bench Unit			
PRH-60C	Chassis Unit ±120V at ±60mA	300	287	269
PR-300	Bench Unit			
PR-300C	Chassis Unit			
PR-300R	3½" Rack Unit ±15V at ±300mA	285	272	254

SPECIAL POWER SUPPLIES

		1-4
SPDR-1	Chopper Driver Unit	$ 95
6510	DC-DC Polarity Inverter	79

TRANSCONDUCTORS

PL1-N/P	Dual Logarithmic Transconductors	$ 40
PPL1-N/P		
PL2-N/P	Quadruple Logarithmic Transconductors	60
PPL2-N/P		
PL3	Quadruple Logarithmic Transconductors	60
PPL3		
PPL4-N/P	Logarithmic Transconductors — Temperature Compensated	59
SPL4-N/P	Logarithmic Transconductors — Temperature Compensated	97
SPLR-N/P	Log Ratio Transconductor	290
PSQ-N/P	Quadratic Transconductor — Squaring & Rooting	195
SPLOG-N/P	Logarithmic Transconductor	195
SPSIN-N/P	Sinusoidal Transconductor	195
SPCOS-N/P	Sinusoidal Transconductor	195
SPFX-N/P	Arbitrary Function Fitter	195

UNIT OPERATORS

SPL4A-N/P	Logarithmic Operator	$227
SPLRA-N/P	Log-Ratio Operator	390

SWITCHING UNITS

SPG1	Diode Current Gate	$ 70
SPREL	Relay Unit	70
SPT&H	Track & Hold Modulator	195

Q3 OPERATIONAL MODULES & POWER SUPPLIES

Q3-A1P	Stabilized onefold (SP656M), self-powered including line cord and dress covers	$466
Q3-A2P	Differential onefold (SP2B), self-powered including line cord and dress covers	495
Q3-M1P	Multiplier/Divider, self-powered, including line cord and dress covers	980
Q3-M2P	Multiplier/Divider, self-powered, including line cord and dress covers	880
Q3-UP	Uncommitted Q3 Module with power supply (±15V at ±30mA) —	
	With line cord	140
	Without line cord	135
Q3-U	Uncommitted Q3 Module	
	With rear connectors	29
	Without rear connectors	20
QPR-300	Regulated Power Supply (±15V at ±300mA)	
	Bench Unit with line cord and dress covers	300
QPRH-60	Regulated Power Supply (±120V at ±60mA)	
	Bench Unit with line cord and dress covers	315
Q3	Accessories and Hardware (See 4-page brochure Q3 modules & cases)	

OPERATIONAL MANIFOLDS

MP	Fourfold self-powered, including 4 EP85AU Amplifiers	$390
RP	Fivefold self-powered, including 5 EP85AU Amplifiers	495

ACCESSORIES

OP-0	Unwired P-size plug-in board and 10-terminal socket	$4.30
P-0	Unwired P-size plug-in unit metal case and 10-terminal mating socket	8
SP-0	Unwired SP-size plug-in unit, metal case and 15-terminal mating socket	11.50
OSP-0	Unwired SP-size plug-in board and 15 terminal mating socket	5.50
MAK-1	Mechanical Accessory Kit for MP or Q3-A1P	72
CCK	COMPUTING COMPONENT KIT for MP or Q3-A1P	
-U	Electrical components only	60
-M	Plug-mounted electrical components	151

PHILBRICK VACUUM TUBE EQUIPMENT

OPERATIONAL AMPLIFIERS

		1-4	5-14	15-24
K2-W		$ 25	$ 25	$ 24
K2-XA		45	45	43
K2-WJ		65	63	61
K2-YJ		80	79	77
SK2-V		65	65	64
K2-P, PA	Stabilizer	52	52	52
K2-PJ	Stabilizer	85	81	81
SK-2P	Stabilizer	70	70	68
K2-BJ	Booster	54	51	48
SK2-B	Booster	44	44	44
USA-3		98	89	79
USA-3-M3		128	120	120
UPA-2		149	142	142
USA-4JX		198	193	193
USA-4JT		198	193	193

REGULATED POWER SUPPLIES

R-100B	RACK PANEL	±300V at ±100mA	$225	$220	*
R-300	RACK PANEL	±300V at ±300mA	475	465	*
R-600	RACK PANEL	±300V at ±600mA	775	760	*

OPERATIONAL MANIFOLDS

6009	Tenfold (10 K2-Ws)	$520
HK	Tenfold (10 K2-Ws)	435
MK	Fourfold, Self-powered (4 K2-Ws)	465
K7-A10	Tenfold, Stabilized (10 USA-3s)	1365
SK5-H	Fivefold, Stabilized (5 SK2-V + SK2-P + Booster)	1150

UNIT OPERATORS

SK5-U	Universal Linear Operator	$1850
SK5-M	Arbitrary Multiplier/Divider	1850
SK5F	Arbitrary Function Component	1950
5934	Display System	9800
MU/DV	Duplex Multiplier/Divider ±50V	775
	±100V	820

ACCESSORIES

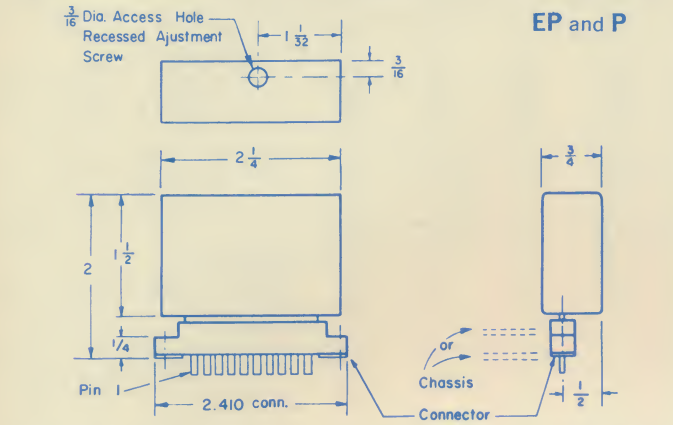
AP-2	Signal Cords (Banana-type connectors) Black or Gray/8″, Blue or Green/24″, Red or Yellow/36″ (All stackable)	$ 3
PA	Plug Adaptors, telephone male	2
SK5-R	Relay Control Component	375

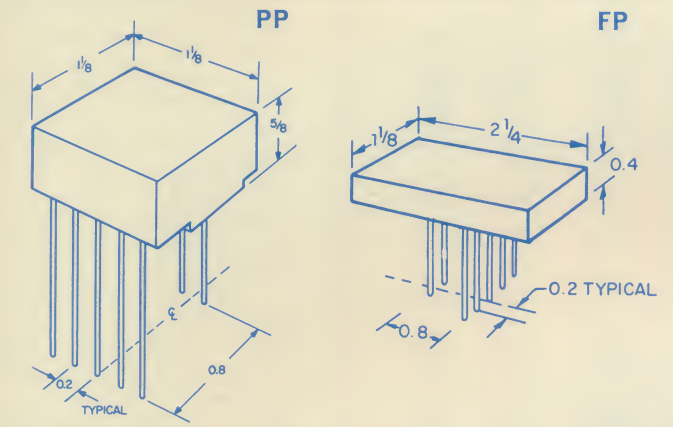
PHILBRICK RESEARCHES, INC.
ALLIED DRIVE at ROUTE 128, DEDHAM, MASSACHUSETTS 02026

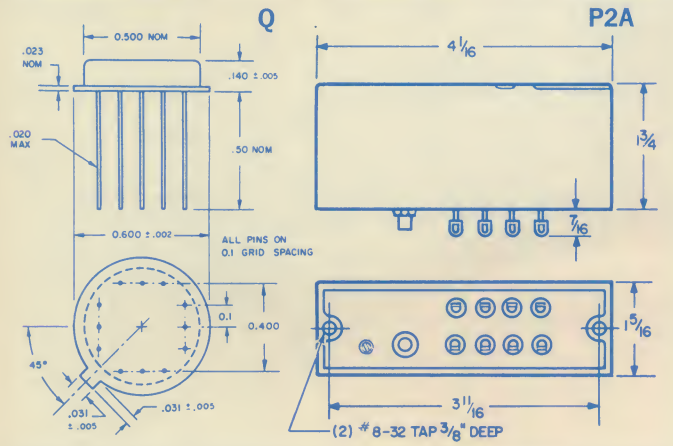
BULLETIN 6111
December 1966

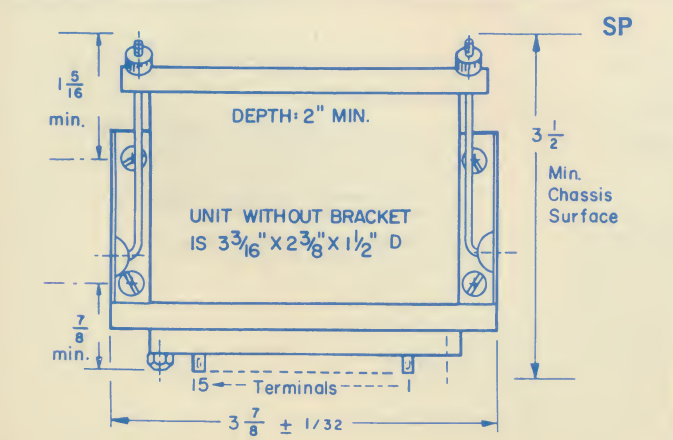
Philbrick Solid State Operational Amplifiers

PHILBRICK produces a wide variety of cool, reliable, solid state operational amplifiers to meet the gamut of application requirements in measurement, computing, control, data processing, and testing. The units shown in this chart are the most popular types now in production. In addition to these, Philbrick is developing new and improved types to meet the ever-increasing challenges to operational amplifier performance. Besides basic amplifiers, one can obtain voltage and current boosters, regulated dc power supplies, non-linear transconductors and operational manifolds from Philbrick. You are invited to discuss the application of operational amplifiers to the solution of your problems with Philbrick or our nearest Representative.









UTILITY-GRADE

Philbrick Utility-Grade Amplifiers, identified by the letter "U" following the family number (e.g.PP85AU), are identical to premium-grade prototypes in circuitry, layout, manufacturing techniques, and the exclusive use of silicon transistors and first-grade passive components from leading U. S. manufacturers.

The substantial price difference between premium and utility-grade amplifiers is achieved by the following means:

The use of silicon transistors encapsulated in highly moisture-resistant silicone plastic (Note: not epoxy!) instead of hermetically-sealed amplifiers.

Use of capacitors which are guaranteed from −55 to +85°C, instead of the −65 to +125°C units normally used in Premium-Grade products.

All room-temperature tests are carried out with the thoroughness that has earned Philbrick an enviable reputation for reliability; **complete** temperature tests are run on representative samples of each production run to confirm compliance with published specifications.

Use of date codes and go-no-go tests instead of serial numbers and recording of data as normally required for all premium units (Government Inspection and/or certified test results are available, upon request, for **premium** units.)

In performance, the Utility-Grade amplifiers (except those in the P2 Series) are identical to their Premium-Grade counterparts. As temperature tests are conducted on samples only, tolerances outside the 10°–60°C range are relaxed as compared with the corresponding specifications for the premium amplifier.

Philbrick Utility-Grade amplifiers may be substituted in virtually all applications for which their Premium-Grade counterparts are and have been originally recommended.

CURRENT COMPENSATION

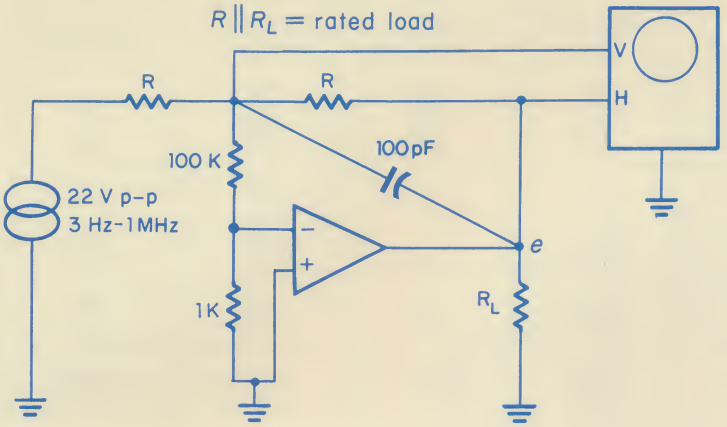
Philbrick differential operational amplifier families P35 through P85 contain input stages with matched pairs of junction transistors in a common emitter configuration. Emitter current being kept constant, each transistor requires a "housekeeping" current into its base amounting to emitter current divided by β (current gain). By selecting high-β transistors and low emitter currents, these base currents can be made as small as 10^{-8} amperes, but they can never be eliminated, and they increase as temperature decreases. If the base currents of input transistors are not supplied by current sources within the amplifier, an output voltage error will result because this offset current produces a voltage drop across the feed-back impedance (in an inverter) or the signal source impedance (in a voltage follower).

The simplest form of base current supply is a resistor from +B to each base. P45A, P55A, P65A and P85A families have these built in, while the proper resistance values for external installation are marked on their PP equivalents. Although these current trim resistors are inexpensive, they are most effective within narrow temperature limits and where high common-mode voltages do not occur. After all, β, and with it base current do change with temperature, and a resistor is a constant current source only as long as the voltage across it remains constant!

Philbrick Current Compensated Amplifiers, identified by the letter C following the family number, have built-in base current sources which closely track current demand over the entire operating temperature range.

The P35C and P85C series contain a sophisticated compensating circuit which leaves the outstanding common mode voltage rejection ratio, the common mode voltage range, and the input impedances unaffected. An additional feature of this compensating circuit is a provision for nulling either input current completely by applying an adjustable voltage bias (±5 volts maximum) to a terminal provided for the purpose. The P45C and P65C series contain a simpler compensating circuit which provides a fivefold decrease in offset current over the entire temperature range, but also reduces the common mode rejection ratio, the common mode voltage range, and the input impedance.

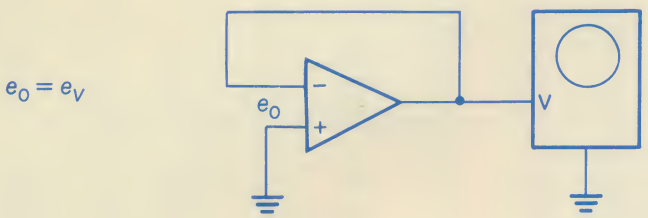
AMPLIFIER TEST CIRCUITS



OPEN LOOP GAIN & OUTPUT CAPABILITY

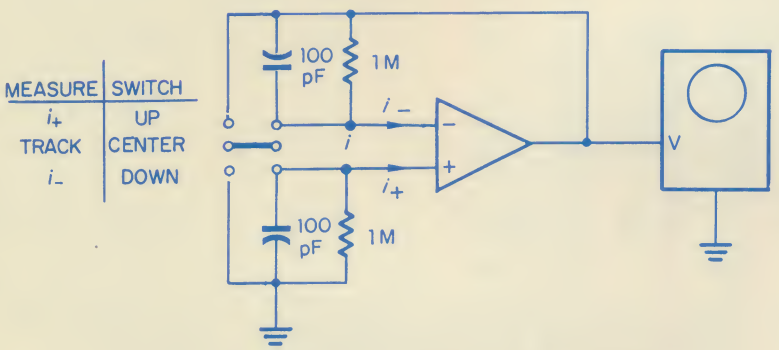
DC open loop gain, A, may be measured at 20 Hz. Of chopper stabilized amplifiers, only the main amplifier gain is measured in this manner, overall DC gain being too high to measure. For SP2A the gain measurement should be carried out at no more than 3 Hz.

$$A = 101\,\frac{e_H}{e_V}$$



VOLTAGE OFFSET

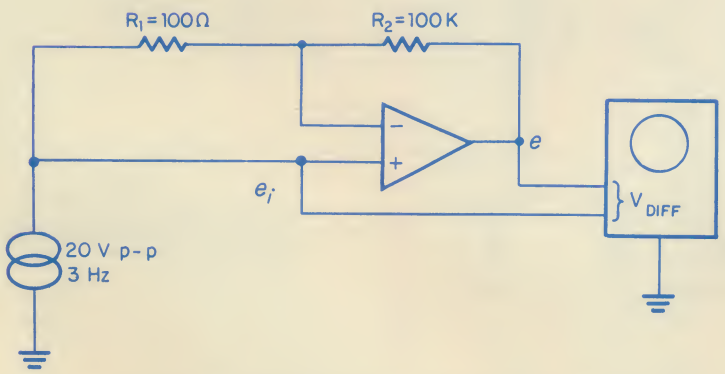
Voltage offset, e_0, vs. temperature and/or time may be measured after the voltage offset central has been adjusted for zero output at room temperature. For best accuracy allow the amplifier to warm up for 30 minutes before adjusting to zero.



INPUT CURRENT

Input currents should be measured after the voltage offset has been nulled. If amplifiers have too little input current to be measured in this manner (SP2A, P25A, Q25AH, chopper stabilized amplifier) the 1MΩ resistors should be omitted, and the output change timed. i = C de/dt or 1 pA = 10 mV/sec.

$\frac{i_-}{i_- = \frac{+e_V}{1M\Omega}}$	$\frac{\text{TRACK}}{i_+ - i_- = \frac{-e_V}{1M\Omega}}$	$\frac{i_+}{i_- = \frac{-e_V}{1M\Omega}}$



COMMON MODE REJECTION

The common mode rejection ratio measurement must be carried out using oscilloscope having itself good CMRR. It will be found that the CMRR of the SP2A is too high to measure in this manner.

$$\text{CMRR} = \left(\frac{e_i}{e - e_i}\right)\left(\frac{R_2}{R_1} + 1\right) \text{ provided } A \gg \text{CMRR}$$

Engineering Representatives

Alabama	Huntsville	205-536-8393	Illinois	Chicago	312-676-1100	New York	Buffalo	716-835-6186	Texas	Dallas	214-526-8316
Arizona	Phoenix	602-265-3629			312-676-1101		Syracuse	315-446-0220		Houston	713-781-1441
California	Los Angeles	213-937-0780	Indiana	Indianapolis	317-356-4249		Valley Stream	516-561-7791	Utah	Salt Lake City	801-466-4924
	Mountain View	415-969-9020	Louisiana	New Orleans	504-242-5575	North Carolina	Winston-Salem	919-725-5384	Virginia	Alexandria	703-836-1800
	San Diego	714-222-1121	Maryland	Baltimore	301-727-1999			919-725-5385		Newport News	703-245-8272
Colorado	Denver	303-733-3701	Massachusetts	Wakefield	617-245-5100	Ohio	Dayton	513-298-9964	Washington	Seattle	206-723-3320
Connecticut	Hartford	203-233-5503	Michigan	Detroit	313-838-7324		Westlake	216-871-8000	New York (Export)	New York	212-246-2133
	Greenwich	203-661-5140	Minnesota	Minneapolis	612-545-4481	Oklahoma	Tulsa	918-627-6199			
Florida	Ft. Lauderdale	305-564-8000	Missouri	St. Louis	314-831-0015	Pennsylvania	Philadelphia	215-277-0559	Canada	Quebec — Montreal	514-482-9750
	Ft. Walton Beach	904-243-6424	New Mexico	Albuquerque	505-268-3941		Pittsburgh	412-371-1231		Ontario — Toronto	416-789-4325
	Orlando	305-425-5505									
Georgia	Atlanta	404-939-1674									

CHARACTERISTICS Typical at +25°C unless otherwise indicated	PP12Q Battery operated High input impedance Low offset current	PP18Q Battery operated Differential	PP25A High input impedance Low offset current	Q25AH Differential Wideband Low offset current	PP35A Differential High input impedance Low voltage offset	PP35C Differential Input current compensated High input impedance Low offset voltage	PP45 Ultra wideband Large output current
1. **VOLTAGE GAIN (DC open loop)**							
At +25°C, rated load, ...min.	5,000	5,000	40,000	20,000	100,000	100,000	50,000
10 kΩ load, ...min.	20,000	20,000	80,000	35,000	200,000	200,000	200,000
100 kΩ load, ...min.	30,000	30,000	150,000	80,000	1,000,000	1,000,000	300,000
At −25°C, rated load, ...min.	2,000	2,000	30,000	15,000	40,000	40,000	20,000
At +85°C, rated load, ...min.	2,000	2,000	60,000	15,000	150,000	150,000	100,000
2. **RESPONSE (open loop, inverting)**							
Small signal: Unity gain-bandwidth ....min.	50 kHz	50 kHz	1.5 MHz	30 MHz ▼	4 MHz	4 MHz	100 MHz
Gain at 1.0 MHz	—	—	2	40	6	6	140
Gain at 10 MHz	—	—	—	4	—	—	14
Large signal: Full output ....min.	1 kHz	1 kHz	10 kHz	0.1 MHz	8 kHz	8 kHz	300 kHz
Rate limit	20 V/ms	20 V/ms	0.6 V/μ-sec	8 V/μ-sec	0.5 V/μ-sec	0.5 V/μ-sec	200 V/μ-sec
3. **INPUT VOLTAGE RANGE**							
Voltage range, both inputs	±0.2 V	±0.5 V	±10 V	±10 V	±10 V	±10 V	±10 V
Voltage range, between inputs ....abs. max.	2.7 V	2.7 V	30 V	30 V	5 V	5 V	5 V
CMRR, DC ....min.	1000:1	5000:1	1000:1	5,000:1	20,000:1	20,000:1	1000:1
4. **INPUT IMPEDANCE**							
Between inputs	$10^{11}\Omega$ ‖ 6 pF	0.4 MΩ ‖ 6 pF	$10^{11}\Omega$ ‖ 6 pF	$10^{11}\Omega$ ‖ 3 pF	5MΩ ‖ 5 pF	5MΩ ‖ 5 pF	220 kΩ ‖ 6 pF
Negative input to common	$10^{12}\Omega$ ‖ 6 pF	15 MΩ ‖ 6 pF	$10^{12}\Omega$ ‖ 6 pF	$10^{12}\Omega$ ‖ 6 pF	$2(10^9)\Omega$ ‖ 27 pF	$2(10^9)\Omega$ ‖ 27 pF	33 MΩ ‖ 0.01μF
Positive input to common	$10^{12}\Omega$ ‖ 6 pF	15 MΩ ‖ 6 pF	$10^{12}\Omega$ ‖ 6 pF	$10^{12}\Omega$ ‖ 6 pF	$2(10^9)\Omega$ ‖ 27 pF	$2(10^9)\Omega$ ‖ 27 pF	33 MΩ ‖ 6 pF
5. **INPUT VOLTAGE OFFSET**							
Zero adjustment (external)	10 kΩ Rhst.	10 kΩ Rhst.	5 kΩ Rhst.	10 kΩ & 250 kΩ Pot.	2.5 kΩ Pot.	2.5 kΩ Pot.	50 kΩ Rhst.
Vs Temp. (+10°C to +60°C), ...max.	3 mV	3 mV	3 mV	3 mV	1 mV	1 mV	2.5 mV
Vs Temp. (−25°C to +85°C), ...max.	6 mV	6 mV	6 mV	6 mV	3 mV	3 mV	6 mV
Vs Time (per day)	50 μV	50 μV	50 μV	50 μV	25 μV	25 μV	100 μV
Vs Time (½ hour)	10 μV	10 μV	10 μV	10 μV	10 μV	10 μV	15 μV
6. **INPUT CURRENT OFFSET**							
25°C ....max.	−100 pA	±50 nA *	−150 pA	−150 pA	+20 nA	±4 nA **	±50 nA*
Vs Temp. (+10°C to +60°C), ...max.	1 nA	200 nA	1 nA	1 nA	20 nA	4 nA	150 nA
Vs Temp. (−25°C to +85°C), ...max.	10 nA	440 nA	10 nA	10 nA	45 nA	10 nA	300 nA
Vs Time (per day)	3 pA	5 nA	3 pA	3 pA	1 nA	1 nA	30 nA
Vs Time (½ hour)	1 pA	0.5 nA	1 pA	1 pA	0.1 nA	0.1 nA	3 nA
7. **INPUT NOISE**							
(a) Flicker (0.016 to 1.6 Hz)							
voltage p-p	5 μV	5 μV	5 μV	5 μV	10 μV	10 μV	5 μV
current p-p	2 pA	0.25 nA	2 pA	2 pA	0.05 nA	0.05 nA	0.5 nA
(b) Broadband (1.6 to 160 Hz)							
voltage rms	2 μV	1 μV	2 μV	2 μV	10 μV	10 μV	1 μV
current rms	3 pA	30 pA	1 pA	1 pA	6 pA	6 pA	600 pA
(c) Broadband (0.16 to 16 kHz)							
voltage rms	2 μV	1 μV	2 μV	2 μV	10 μV	10 μV	1 μV
current rms	3 pA	30 pA	3 pA	3 pA	6 pA	6 pA	600 pA
8. **OUTPUT (−25°C to +85°C)**							
Voltage	±1 V	±1 V	±11 V	±11 V	±11 V	±11 V	±10 V
Current	±2 mA	±2 mA	±2.2 mA	±2.2 mA	±2.2 mA	±2.2 mA	±20 mA
Load (rated)	500 Ω	500 Ω	5 kΩ	5 kΩ	5 kΩ	5 kΩ	500 Ω
9. **POWER REQUIREMENTS** ‡							
Voltage	±1.35 V	±1.35 V	±15 V	±15 V	±15 V	±15 V	±15 V
Current from positive supply: (Quiescent)	0.8 mA	0.4 mA	4.6 mA	6.6 mA	6 mA	6 mA	4 mA
(Full Load)	2.8 mA	2.4 mA	4.6 mA	6.6 mA	6 mA	6 mA	23 mA
Current from negative supply: (Quiescent)	0.8 mA	0.4 mA	4.6 mA	6.6 mA	6 mA	6 mA	4 mA
(Full Load)	2.8 mA	2.4 mA	6.8 mA	8.8 mA	8.2 mA	8.2 mA	23 mA
10. **TEMPERATURE RANGE** (degrees Centigrade)							
Operating: Rated	−25 to +85	−25 to +85	−25 to +85	−55 to +125	−25 to +85	−25 to +85	−25 to +85
Derated specifications ....max.	−55 to +100	−55 to +100	−55 to +100		−55 to +100	−55 to +100	−55 to +100
Storage ....max.	−62 to +125	−62 to +125	−62 to +125	−62 to +150	−62 to +125	−62 to +125	−62 to +125
PRICE (quantity 1-4) Price of "Alternate Forms" may be slightly different. Prices may change without notice.	$145	$85	$135	$180	$98	$118	$118
ALTERNATE FORMS These units belong in the same family as the prototype because they have nearly equivalent circuit configurations. They may differ significantly from the listed types in electrical or physical characteristics, or applications considerations. Philbrick Researches welcomes your inquiry regarding these and other modified forms of standard units.	**P12Q** ■ $145	**P18Q** ■ $85	**PP25C** and **P25C** ■ have input currents approximately 1/10 of those given for **PP25A** at any given temperature. $145 **P25A** ■ $135	**P25AH** ▼ ■ $154	**PP35A1** and **P35A1** ■ are units selected for less than 1 mV input voltage offset (−25°C to +85°C). $128 **P35A** ■ $98	**PP35C1** and **P35C1** ■ are units selected for less than 1 mV input voltage offset (−25°C to +85°C). $128 **P35C** ■ $118	**P45A** ■ $118
UTILITY GRADE Where indicated a utility grade equivalent denoted by the letter U following the model designation, is available at reduced price. Utility grade amplifiers have identical performance with their premium grade equivalents in the temperature range 0-60°C. Storage temperatures below −55°C and above +85°C and certified test data are not available.	**EP12QU** ▲ $108 **PP12QU** $108	**EP18QU** ▲ $59 **PP18QU** $59	**EP25AU** ▲ $85 **PP25AU** $79		**EP35AU** ▲ $60 **PP35AU** $54		**EP45AU** ▲ $87 **PP45U** $89

SUGGESTED BOOSTER TYPES (used with operational amplifiers for voltage or current boost; connected inside the loop)

		Physical Form	Price (quantity 1-4)
P66A	delivers ±10 V at ±100 mA with external "Boost" resistors connected; ±20 mA without.	P	$39
PP66A	delivers same power output as Model P66A.	PP	$40
P5	delivers ±10 V at ±20 mA; physical companion of P2A.	P2A	$48
OSPB -50/50	delivers ±50 V at ±50 mA with external "Boost" resistors connected; ±10 mA without; has DC gain of 7; requires ±60 V supplies.	OSP	$85
OSPB-100/10	delivers ±100 VDC at ±10 mA with external "Boost" resistors connected; ±1.5 mA without; has DC gain of 20; requires ±120 VDC supplies.	OSP	$85

FLAT-PROFILE PACKAGE

"FLAT-PROFILE" amplifiers (FP), only 0.4" in height, are available in OEM quantities to permit 0.5" printed circuit board spacing. Most "PP" amplifiers described above and some boosted models not available in the "PP" package may be ordered in the "FP" model.

PP45C Ultra wideband Large output current Input current compensated	PP45L Large output current	PP55A Low cost Premium grade construction	PP65A Versatile	PP65C Versatile Input current compensated	PP65AH Wideband Versatile	PP75A High input impedance	PP85A Differential Low voltage offset	PP85C Differential Low voltage offset Input current compensated
50,000 200,000 300,000 20,000 100,000	50,000 200,000 300,000 20,000 100,000	20,000 40,000 60,000 10,000 30,000	40,000 75,000 180,000 20,000 50,000	40,000 75,000 180,000 20,000 50,000	40,000 75,000 180,000 20,000 50,000	20,000 40,000 80,000 10,000 40,000	50,000 90,000 200,000 20,000 60,000	50,000 90,000 200,000 20,000 60,000
100 MHz 140 14 300 kHz 200 V/μ-sec	1.5 MHz 2 — 10 kHz 0.6 V/μ-sec	1.5 MHz 3 — 20 kHz 1.5 V/μ-sec	1.5 MHz 3 — 20 kHz 1.5 V/μ-sec	1.5 MHz 3 — 20 kHz 1.5 V/μ-sec	20 MHz 25 3 75 kHz 5 V/μ-sec	1.5 MHz 3 — 20 kHz 1.5 V/μ-sec	2 MHz 3 — 10 kHz 0.6 V/μ-sec	2 MHz 3 — 10 kHz 0.6 V/μ-sec
±5 V 5 V 300:1	±10 V 5 V 1000:1	±10 V 5 V 1000:1	±10 V 5 V 1000:1	± 5 V 5 V 300:1	±10 V 5 V 1000:1	±10 V 10 V 1000:1	±11 V 5 V 20,000:1	±11 V 5 V 20,000:1
220 kΩ ‖ 6 pF 15 MΩ ‖ 0.01μF 15 MΩ ‖ 6 pF	220 kΩ ‖ 6 pF 33 MΩ ‖ 1000 pF 33 MΩ ‖ 6 pF	200kΩ ‖ 7pF 15MΩ ‖ 400pF 15MΩ ‖ 8pF	300kΩ ‖ 6pF 44MΩ ‖ 400pF 44MΩ ‖ 6pF	300kΩ ‖ 6pF 22MΩ ‖ 400pF 22MΩ ‖ 6pF	300kΩ ‖ 6pF 44MΩ ‖ 400pF 44MΩ ‖ 6pF	10MΩ ‖ 6pF 500MΩ ‖ 400pF 500MΩ ‖ 6pF	330kΩ ‖ 6pF 500MΩ ‖ 6pF 500MΩ ‖ 6pF	330kΩ ‖ 6pF 500MΩ ‖ 6pF 500MΩ ‖ 6pF
50 kΩ Rhst. 2.5 mV 6 mV 100 μV 15 μV	50 kΩ Rhst. 2.5 mV 6 mV 100 μV 15 μV	50 kΩ Rhst. 2 mV 6 mV 100 μV 25 μV	50 kΩ Rhst. 1.5 mV 4 mV 50 μV 10 μV	50 kΩ Rhst. 1.5 mV 4 mV 50 μV 10 μV	50 kΩ Rhst. 1.5 mV 4 mV 50 μV 10 μV	50 kΩ Rhst. 3 mV 12 mV 100 μV 25 μV	50 kΩ Rhst. 1 mV 3 mV 50 μV 10 μV	50 kΩ Rhst. 1 mV 3 mV 50 μV 10 μV
±50 nA 50 nA 150 nA 30 nA 3 nA	±50 nA* 150 nA 300 nA 30 nA 3 nA	±50 nA* 300 nA 600 nA 30 nA 3 nA	±50 nA* 150 nA 300 nA 10 nA 1 nA	±50 nA 50 nA 100 nA 10 nA 1 nA	±50 nA* 150 nA 300 nA 10 nA 1 nA	+ 20 nA 20 nA 60 nA 1 nA 0.1 nA	±50 nA* 150 nA 300 nA 5 nA 0.5 nA	±50 nA ** 50 nA 100 nA 5 nA 0.5 nA
5 μV 0.5 nA 1 μV 600 pA 1 μV 600 pA	5 μV 0.5 nA 1 μV 60 pA 1 μV 60 pA	15 μV 1 nA 2 μV 100 pA 2 μV 100 pA	10 μV 0.5 nA 1 μV 60 pA 1 μV 60 pA	10 μV 0.5 nA 1 μV 60 pA 1 μV 60 pA	10 μV 0.5 nA 1 μV 60 pA 1 μV 60 pA	20 μV 0.05 nA 10 μV 6 pA 10 μV 6 pA	5 μV 0.25 nA 1 μV 30 pA 1 μV 30 pA	5 μV 0.25 nA 1 μV 30 pA 1 μV 30 pA
±10 V ±20 mA 500 Ω	±10 V ±20 mA 500 Ω	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ
±15 V 4 mA 23 mA 4 mA 23 mA	±15 V 4 mA 23 mA 4 mA 23 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 5.5 mA 7.7 mA 5.5 mA 5.5 mA	±15 V 4 mA 4 mA 4 mA 6.2 mA	±15 V 4 mA 4 mA 4 mA 6.2 mA
−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125	−25 to +85 −55 to +100 −62 to +125
$135	$95	$49	$60	$75	$64	$98	$60	$80
P45C ■ $133	**P45Al** ■ $95 **PP45CL** and **P45CL** ■ have input current offsets and common mode parameters identical to those of **PP45C** $110	**PP55AH** and **P55AH** ● are stable wide-band versions. $53 **P55A** ● $49	**P65A** ■ $65 **PP65Q** $64 and **P65Q**■ $69 have ±0.9 mA quiescent battery drain, ±0.5 mA full output.	**PP65CH** $79 and **P65CH** ■ $84 are wide-band versions **P65C** ■ $80	**P65AH** ■ $69	**P75A** ■ $98	**PP85A1** and **P85A1** ■ are units selected for less than 1 mV input voltage offset (−25°C to +85°C). $70 and $75 **P85A** ■$65	**P85C** ■ $80
	EP45ALU ▲ $63 **PP45LU** $65	**EP55AU** ◆ $19 **PP55AU** $15 **EP55AHU** ◆ $23 **PP55AHU** $19	**EP65AU** ▲ $31 **PP65AU** $30 **EP65QU** ▲ $35 **PP65QU** $34		**EP65AHU** ▲ $35 **PP65AHU** $34	**P75AU** ■ $68 **PP75AU** $68	**EP85AU** ▲ $31 **PP85AU** $25	

PHILBRICK
RESEARCHES

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U.S.A.

Q85AH Differential wideband Low voltage offset	SP2A Differential Ultra low offset current Floating input	SP65A † Stabilized	SP65AH † Stabilized Wideband	SP656 † Stabilized Large output current	SP456† Stabilized Wideband Large output current	CHARACTERISTICS Typical at +25°C unless otherwise indicated
20,000 40,000 80,000 15,000 15,000	20,000 40,000 150,000 10,000 (0°C) 10,000 (65°C)	10^7 2×10^7 4×10^7 5×10^6 4×10^7	10^7 2×10^7 4×10^7 5×10^6 4×10^7	5×10^7 10^8 2×10^8 2.5×10^7 10^8	10^8 4×10^8 4×10^8 5×10^7 2×10^8	1. **VOLTAGE GAIN (DC open loop)** At +25°C, rated load, ...min. 10 kΩ load, ...min. 100 kΩ load, ...min. At −25°C, rated load, ...min. At +85°C, rated load, ...min.
30 MHz ▼ 50 5 0.1 MHz 8 V/μ-sec	75 kHz — — 1.1 kHz .066 V/μ-sec	1.5 MHz 3 — 20 kHz 1.5 V/μ-sec	20 MHz 25 2.5 75 kHz 5 V/μ-sec	1.5 MHz 3 — 20 kHz 1.5 V/μ-sec	100 MHz 140 14 300 kHz 200 V/μ-sec	2. **RESPONSE (open loop, inverting)** Small signal: Unity gain-bandwith .....min. Gain at 1.0 MHz Gain at 10 MHz Large signal: Full output .....min. Rate limit
±11 V 10 V 20,000:1	±300 V 15 V Infinite	±0.1 V 0.5 V —	±0.1 V 0.5 V —	±0.1 V 0.5 V —	±0.1 V 0.5 V —	3. **INPUT VOLTAGE RANGE** Voltage range, both inputs Voltage range, between inputs ....abs. max. CMRR, DC ..... min.
2MΩ ‖ 3pF 500MΩ ‖ 5pF 500MΩ ‖ 5pF	10^{10}Ω ‖ 500 pF 10^{12}Ω ‖ 5 pF 10^{12}Ω ‖ 5 pF	— 1.3MΩ ‖ 300pF —	— 1.3 MΩ ‖ 300pF —	— 1.3 MΩ ‖ 300pF —	— 1.3 MΩ ‖ 0.01μF —	4. **INPUT IMPEDANCE** Between inputs Negative input to common Positive input to common
10 kΩ & 250 kΩ Pot. 1 mV 3 mV 50 μV 10 μV	Built-in — 6 mV (0° to 65°C) 100 μV 10 μV	1MΩ & 100 kΩ Pot. 20 μV (5 μV typ.) 50 μV (20 μV typ.) 1 μV 1 μV	1MΩ & 100 kΩ Pot. 20 μV (5 μV typ.) 50 μV (20 μV typ.) 1 μV 1 μV	1MΩ & 100 kΩ Pot. 20 μV (5 μV typ.) 50 μV (20 μV typ.) 1 μV 1 μV	1MΩ & 100 kΩ Pot. 20 μV (5 μV typ.) 50 μV (20 μV typ.) 1 μV 1 μV	5. **INPUT VOLTAGE OFFSET** Zero adjustment (external) Vs Temp. (+10°C to +60°C), ...max. Vs Temp. (−25°C to +85°C), ...max. Vs Time (per day) Vs Time (½ hour)
220 nA 220 nA 440 nA 5 nA 0.5 nA	±1 pA — 10 pA (0° to 65°C) 0.1 pA 0.01 pA	10 pA 30 pA 100 pA 10 pA 2 pA	10 pA 30 pA 100 pA 10 pA 2 pA	10 pA 30 pA 100 pA 10 pA 2 pA	10 pA 30 pA 100 pA 10 pA 2 pA	6. **INPUT CURRENT OFFSET** 25°C .....max. Vs Temp. (+10°C to +60°C), ...max. Vs Temp. (−25°C to +85°C), ...max. Vs Time (per day) Vs Time (½ hour)
5 μV 0.25 nA 1 μV 30 pA 1 μV 30 pA	1 μV 1 fA 10 μV p-p — 10 μV 500 pA	6 μV 0.1 nA 10 μV p-p — 1 μV 60 pA	6 μV 0.1 nA 10 μV p-p — 1 μV 60 pA	6 μV 0.1 nA 10 μV p-p — 1 μV 60 pA	6 μV 0.1 nA 10 μV p-p — 1 μV 600 pA	7. **INPUT NOISE** (a) Flicker (0.016 to 1.6 Hz) voltage p-p current p-p (b) Broadband (1.6 to 160 Hz) voltage rms current rms (c) Broadband (0.16 to 16 kHz) voltage rms current rms
±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±11 V ±2.2 mA 5 kΩ	±10 V ±20 mA 500 Ω	±10 V ±20 mA 500 Ω	8. **OUTPUT (−25°C to +85°C)** Voltage Current Load (rated)
±15 V 6 mA 6 mA 6 mA 8.2 mA	±15 V 8 mA 8 mA 6 mA 8.2 mA	±15 V 8 mA 10 mA 7 mA 7 mA	±15 V 8 mA 10 mA 7 mA 7 mA	±15 V 8.75 mA 28 mA 8.75 mA 28.5 mA	±15 V 5 mA 24.5 mA 4.5 mA 24 mA	9. **POWER REQUIREMENTS ‡** Voltage Current from positive supply: (Quiescent) (Full Load) Current from negative supply: (Quiescent) (Full Load)
−55 to +125 −62 to +150	0 to +65 −25 to +85 −55 to +85	−25 to +85 −45 to +85 −55 to +85	−25 to +85 −45 to +85 −55 to +85	−25 to +85 −45 to +85 −55 to +85	−25 to +85 −45 to +85 −55 to +85	10. **TEMPERATURE RANGE** (degrees Centigrade) Operating: Rated Derated specifications .....max. Storage .....max.
$161	$180	$180	$189	$195	$227	**PRICE (quantity 1-4)** Price of "Alternate Forms" may be slightly different. Prices may change without notice.
P85AH ▼■ $98	**P2A** $227 is a wire-in version of **SP2A**. It has no provision for a driven guard **SP2B** $195 has 20 mA output current capability. **SP102** $295 has ±100 V @ 10 mA output capability.					**ALTERNATE FORMS** These units belong in the same family as the prototype because they have nearly equivalent circuit configurations. They may differ significantly from the listed types in electrical or physical characteristics, or applications considerations. Philbrick Researches welcomes your inquiry regarding these and other modified forms of standard units.
	P2AU ▲▲ $130 **SP2AU ▲▲ $138** **SP2BU ▲▲ $145**					**UTILITY GRADE** Where indicated a utility grade equivalent denoted by the letter U following the model designation, is available at reduced price. Utility grade amplifiers have identical performance with their premium grade equivalents in the temperature range 0-60°C. Storage temperatures below −55°C and above +85°C and certified test data are not available.

LEGEND

M — mega — 10^6
k — kilo — 10^3
m — milli — 10^{-3}
μ — micro — 10^{-6}
n — nano — 10^{-9}
p — pico — 10^{-12}
f — femto — 10^{-15}

FOOTNOTES

■ A plug-in version in bright-metal case having similar performance. Voltage offset adjustment built-in.

◆ A plug-in epoxy version having similar performance. Voltage offset adjustment external.

● A plug-in version in bright-metal case having similar performance. No built-in voltage offset adjustment.

▲ A plug-in epoxy version having similar performance Voltage offset adjustment built-in.

* With specified external current trim resistors installed. P models have built-in current trim resistors.

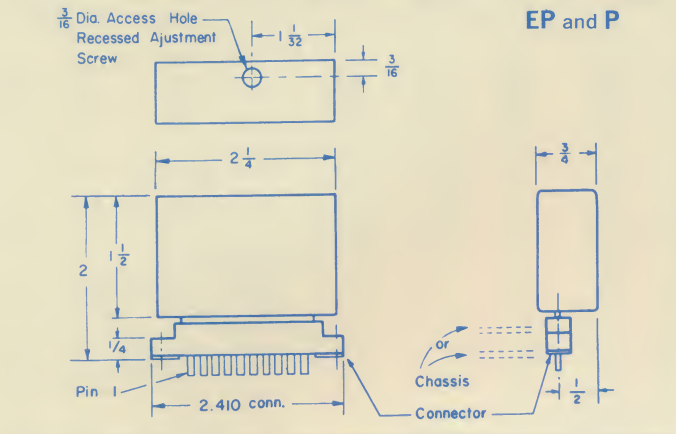
** With "Trim I" terminal grounded. Can be trimmed to zero by voltage bias (±5 V Max.) applied to "Trim I" terminal.

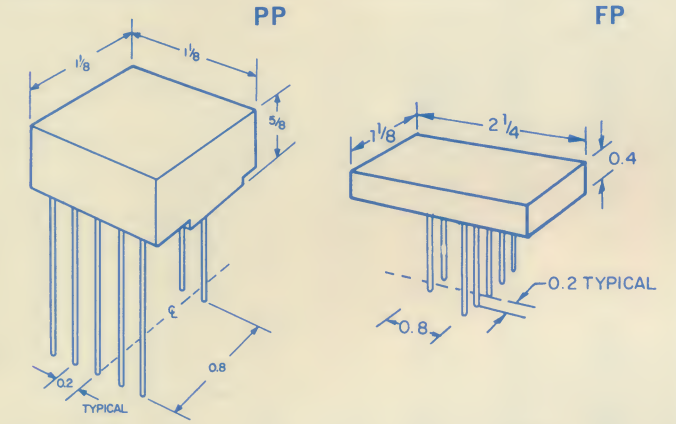
▼ Roll-off network connected externally.

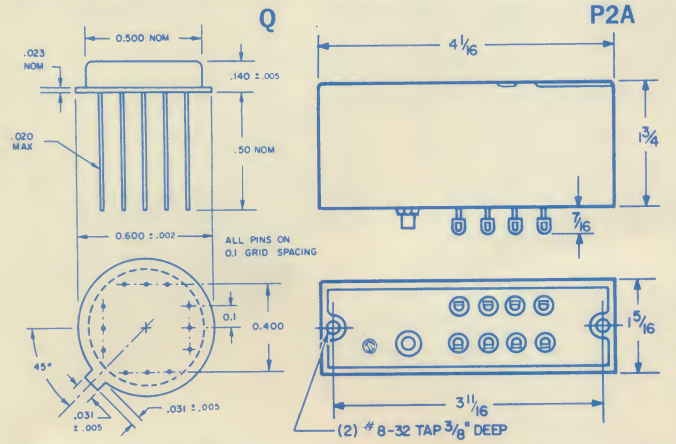
† Specifications shown are for units with mechanical chopper; 6.3 VAC, 50-80 cps at 80 mA is required. Units with photochopper are available for operation below +65°C. In addition to 6.3 VAC, 50-80 cps, 1 mA, the photochopper also requires 115 VAC, 5 mA, at the same frequency and phase.

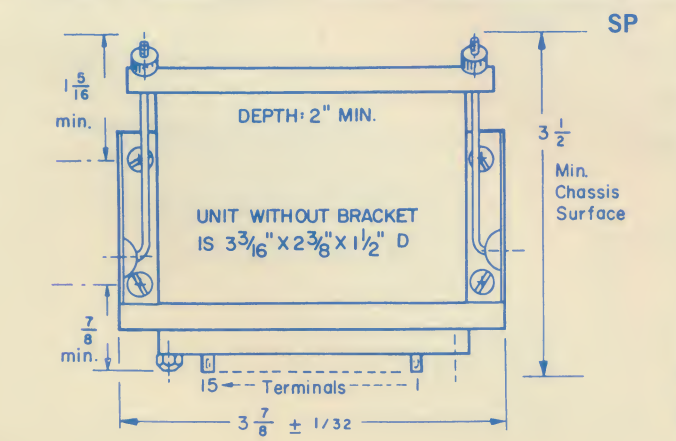
‡ At +85°C power requirements will be 10% higher than those stated at +25°C. For maximum power requirements at any temperature add ±10%.

▲▲ These utility versions have wider tolerances for voltage offset vs temperature, and input current, than premium equivalents.









UTILITY-GRADE

Philbrick Utility-Grade Amplifiers, identified by the letter "U" following the family number (e.g.PP85AU), are identical to premium-grade prototypes in circuitry, layout, manufacturing techniques, and the exclusive use of silicon transistors and first-grade passive components from leading U. S. manufacturers.

The substantial price difference between premium and utility-grade amplifiers is achieved by the following means:

The use of silicon transistors encapsulated in highly moisture-resistant silicone plastic (Note: not epoxy!) instead of hermetically-sealed amplifiers.

Use of capacitors which are guaranteed from −55 to +85°C, instead of the −65 to +125°C units normally used in Premium-Grade products.

All room-temperature tests are carried out with the thoroughness that has earned Philbrick an enviable reputation for reliability; **complete** temperature tests are run on representative samples of each production run to confirm compliance with published specifications.

Use of date codes and go-no-go tests instead of serial numbers and recording of data as normally required for all premium units (Government Inspection and/or certified test results are available, upon request, for **premium** units.)

In performance, the Utility-Grade amplifiers (except those in the P2 Series) are identical to their Premium-Grade counterparts. As temperature tests are conducted on samples only, tolerances outside the 10°–60°C range are relaxed as compared with the corresponding specifications for the premium amplifier.

Philbrick Utility-Grade amplifiers may be substituted in virtually all applications for which their Premium-Grade counterparts are and have been originally recommended.

CURRENT COMPENSATION

Philbrick differential operational amplifier families P35 through P85 contain input stages with matched pairs of junction transistors in a common emitter configuration. Emitter current being kept constant, each transistor requires a "housekeeping" current into its base amounting to emitter current divided by β (current gain). By selecting high-β transistors and low emitter currents, these base currents can be made as small as 10^{-8} amperes, but they can never be eliminated, and they increase as temperature decreases. If the base currents of input transistors are not supplied by current sources within the amplifier, an output voltage error will result because this offset current produces a voltage drop across the feed-back impedance (in an inverter) or the signal source impedance (in a voltage follower).

The simplest form of base current supply is a resistor from +B to each base. P45A, P55A, P65A and P85A families have these built in, while the proper resistance values for external installation are marked on their PP equivalents. Although these current trim resistors are inexpensive, they are most effective within narrow temperature limits and where high common-mode voltages do not occur. After all, β, and with it base current do change with temperature, and a resistor is a constant current source only as long as the voltage across it remains constant!

Philbrick Current Compensated Amplifiers, identified by the letter C following the family number, have built-in base current sources which closely track current demand over the entire operating temperature range.

The P35C and P85C series contain a sophisticated compensating circuit which leaves the outstanding common mode voltage rejection ratio, the common mode voltage range, and the input impedances unaffected. An additional feature of this compensating circuit is a provision for nulling either input current completely by applying an adjustable voltage bias (±5 volts maximum) to a terminal provided for the purpose. The P45C and P65C series contain a simpler compensating circuit which provides a fivefold decrease in offset current over the entire temperature range, but also reduces the common mode rejection ratio, the common mode voltage range, and the input impedance.